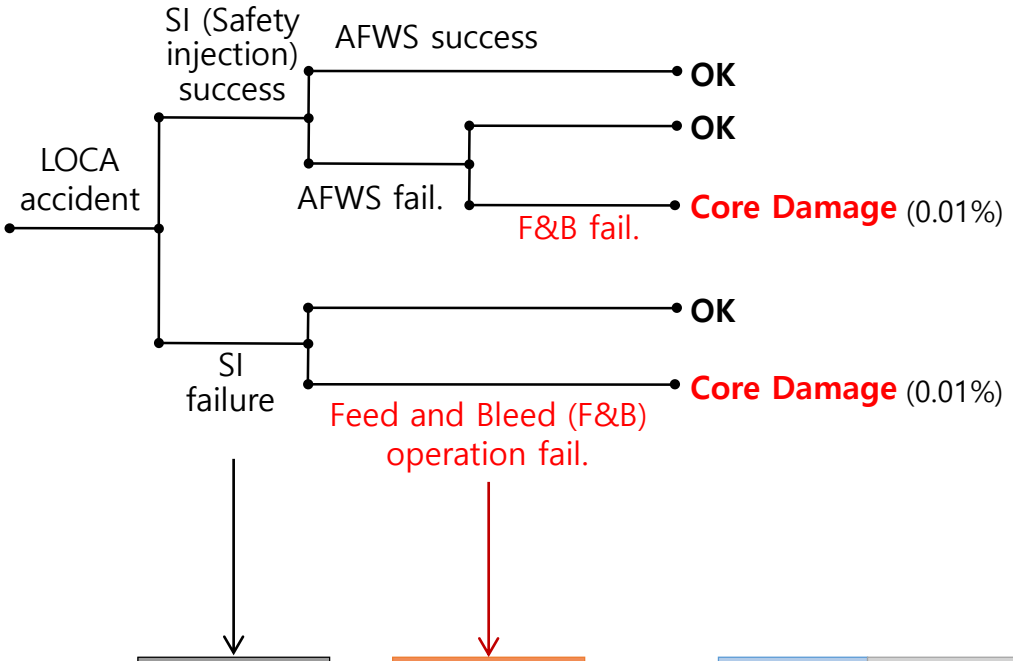
Determining Cue Presentation Time for Diagnosis Error Probability of THERP-like Methods using Confidence Interval of Performance Time

Yochan Kim Korea Atomic Energy Research Institute

Human Reliability Analysis

- In socio-complex industries, human Reliability Analysis (HRA) has been conducted for systematically quantifying the human error probability (HEP).



Operational experience

Expert Judgment

Full-scope simulator

HRA data

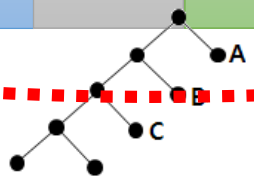
Required human action	HEP
A: Operator omits to open a valve	0.01
B: Operator fails to energize a valve	0.04
C …	…

SI Pump failure probability

Human Error Probability (HEP)

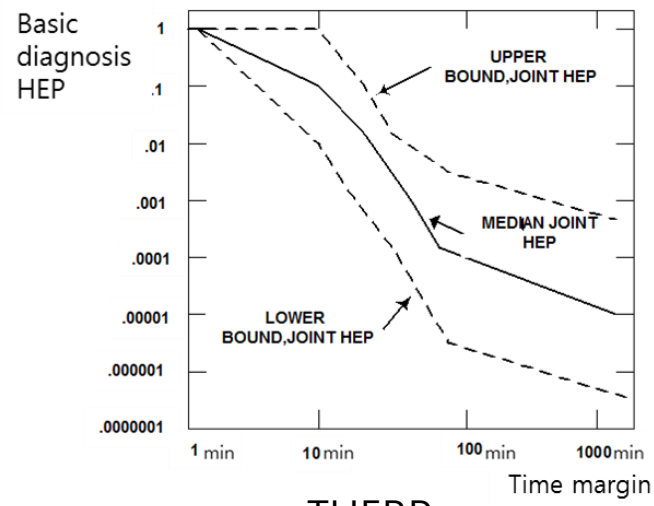
Screening analysis | Task analysis | Error definition | Quantification (Nominal HEP, PSF level)

$HEP_{F\&B\ operation}=0.08$

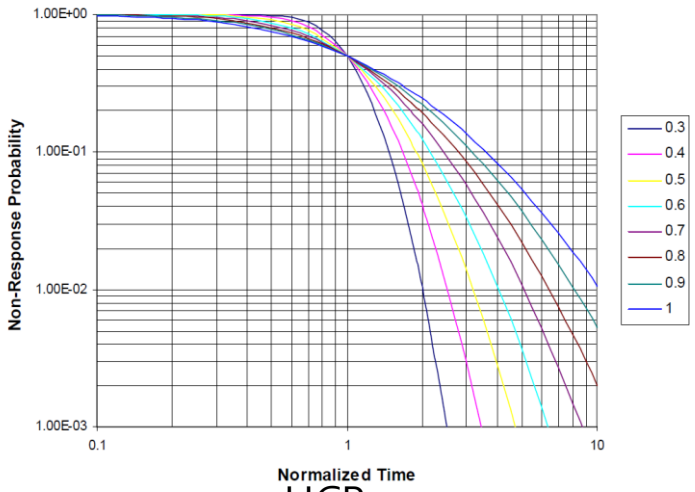


Time Factor in HRA

- The time-related error probability (THERP, HCR, etc.)



<THERP>



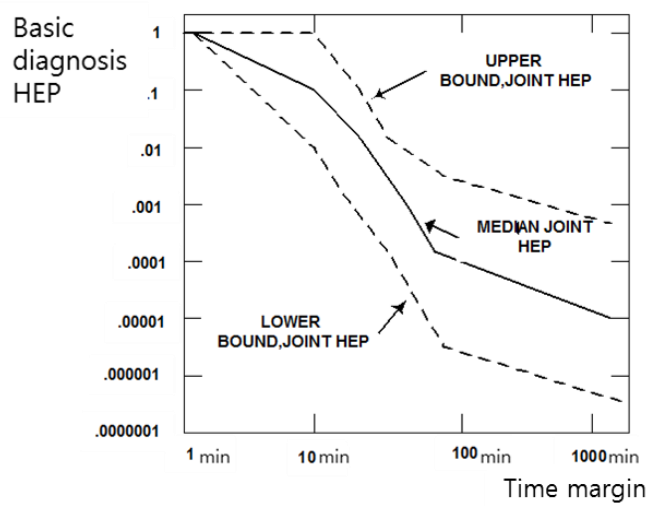
<HCR>

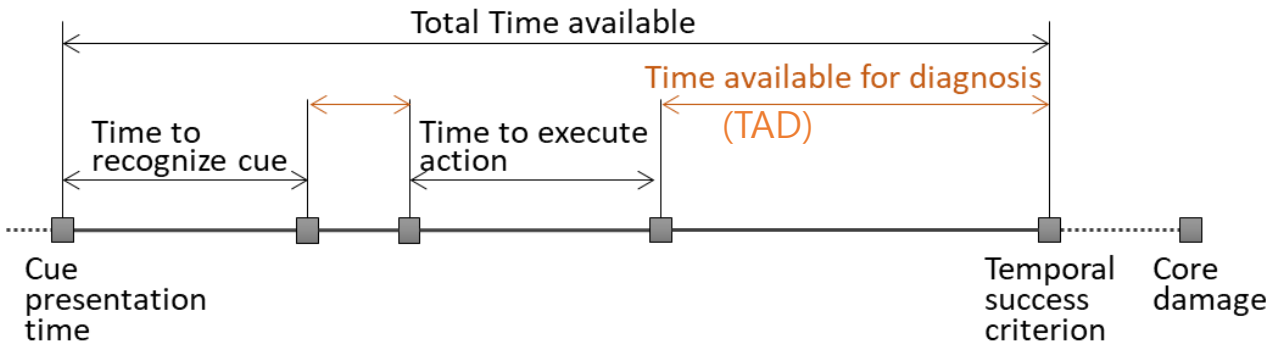
- PSF-based evaluation (HEART, CREAM, SLIM, SPAR-H, Petro-HRA, etc.)

Available time states	Description	Multiplier
Inadequate time	The time required is higher than the time available, i.e., the time margin is negative.	HEP = 1.0
Barely adequate time	The time required is equal to the time available, i.e., the time margin is zero.	10
Nominal time	The time required is slightly less than the time available; a small time margin exists.	1
Extra time	The time required is considerably less than the time available. The time margin is hence larger than zero, but smaller than the time required.	0.1
Expansive time	The time available is much higher than the time required. The time margin is also higher than the time required.	0.01

Time-reliability curve of THERP

- Popular equation to calculate HEP based on time
  - THERP, ASEP, K-HRA, and HuRECA
- Key formula of diagnosis error probability (DEP)
- Use absolute value of time margin (e.g., TAD)





Problem in Current HRAs

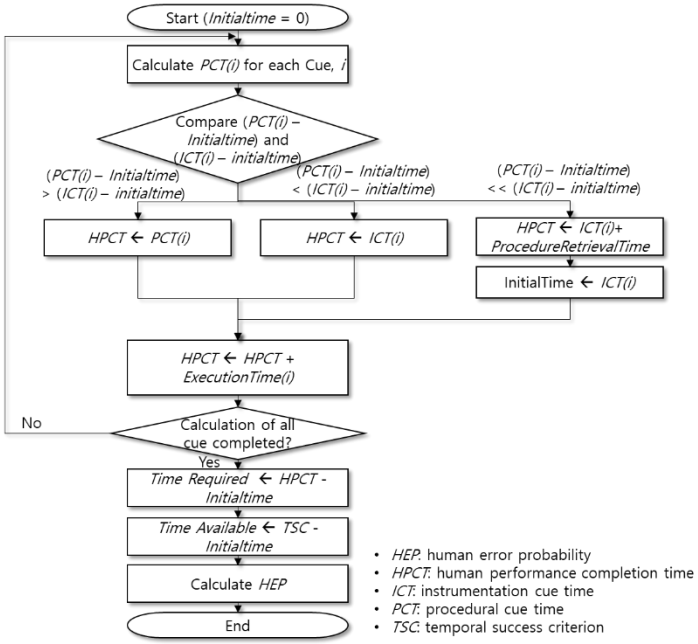
- Cue and its presentation time
  - Significant procedure/indicator
  - TH-analysis, simulation data, walkthrough, expert judgment
- Multiple cues can exist in a given event
  - No decision criterion of critical cue
- Example: Feed and Bleed operation in domestic plants
  - The steam generator (SG) exhaustion time (Tsg)
  - The first opening time of the spring-loaded pilot valve (Tsl)

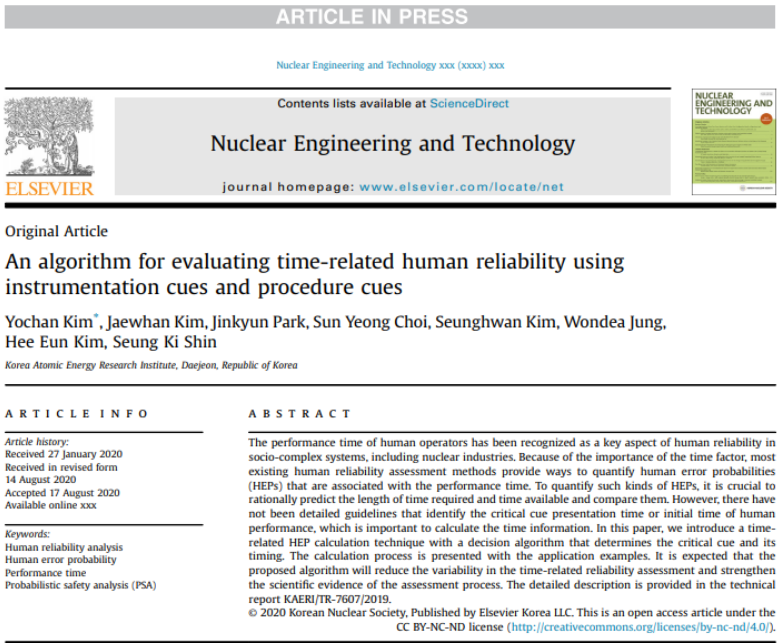
Accident scenario		A	B	C	D
Cue presentation time (unit: min)	Tsg	205	56	38	25
	Tsl	268	452	43	30
Total available time	Ta	293	497	78	40
Time available for diagnosis (TAD)	TAD1 (=Ta-Tsg-Drec-Dexe)	86	439	38	13
	TAD2 (=Ta-Tsl-Drec-Dexe)	23	43	33	8
Diagnosis Error Probability (DEP)	f(TAD1)	6.55E-04	2.04E-04	3.87E-03	1.11E-01
	f(TAD2)	2.37E-02	2.56E-03	6.18E-03	2.02E-01

* Ta: total time available; Tsg: SG exhaustion time; Tsl: first opening time of the spring-loaded pilot valve; Drec: duration for recognition; Dexe: duration for execution; TAD: time available for diagnosis

Problem in Current HRAs

- No decision criterion of critical cue and its timing
  - The HEP is sensitive to the timing of the critical cue
  - HRA results are variable depending on the analyst
- For EMBRACE, HCR/ORE, and SPAR-H, an algorithm for determining a critical cue is proposed
- But, the technique for THERP-like methods has not been developed yet.
  - Use absolute time margin instead of relative time sufficiency





ARTICLE IN PRESS

Nuclear Engineering and Technology xxx (xxxx) xxx

Contents lists available at ScienceDirect

Nuclear Engineering and Technology

journal homepage: www.elsevier.com/locate/net

Original Article

An algorithm for evaluating time-related human reliability using instrumentation cues and procedure cues

Yochan Kim*, Jaewhan Kim, Jinkyun Park, Sun Yeong Choi, Seunghwan Kim, Wondea Jung, Hee Eun Kim, Seung Ki Shin

Korea Atomic Energy Research Institute, Daejeon, Republic of Korea

ARTICLE INFO

Article history:
Received 27 January 2020
Received in revised form
14 August 2020
Accepted 17 August 2020
Available online xxx

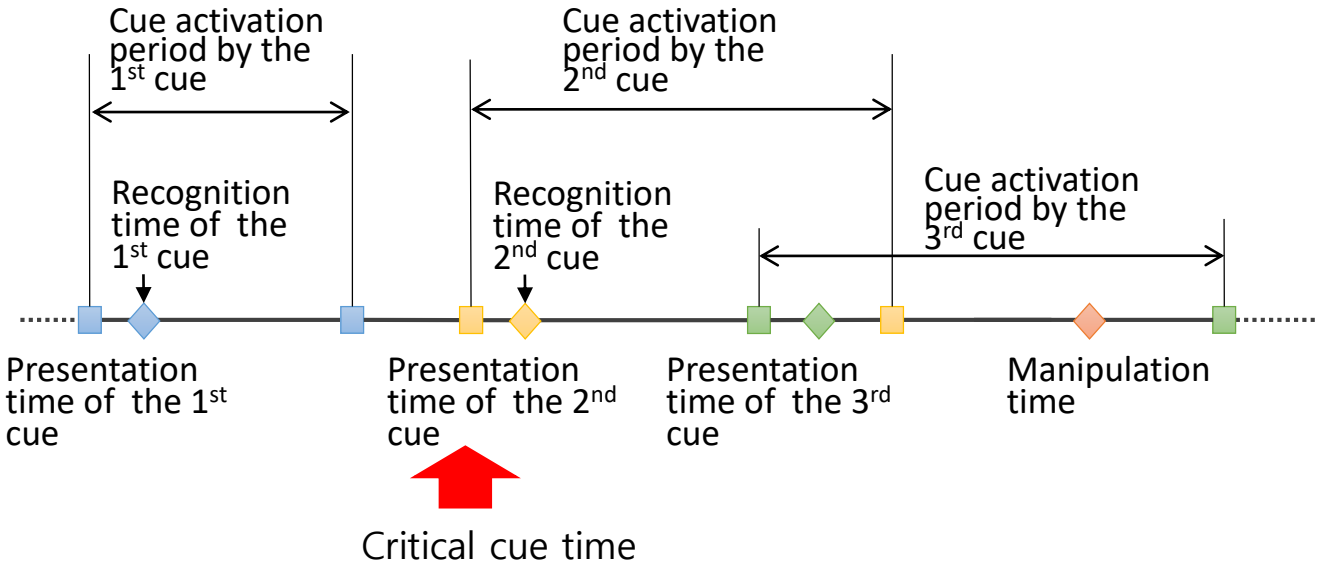
Keywords:
Human reliability analysis
Human error probability
Performance time
Probabilistic safety analysis (PSA)

ABSTRACT

The performance time of human operators has been recognized as a key aspect of human reliability in socio-complex systems, including nuclear industries. Because of the importance of the time factor, most existing human reliability assessment methods provide ways to quantify human error probabilities (HEPs) that are associated with the performance time. To quantify such kinds of HEPs, it is crucial to rationally predict the length of time required and time available and compare them. However, there have not been detailed guidelines that identify the critical cue presentation time or initial time of human performance, which is important to calculate the time information. In this paper, we introduce a time-related HEP calculation technique with a decision algorithm that determines the critical cue and its timing. The calculation process is presented with the application examples. It is expected that the proposed algorithm will reduce the variability in the time-related reliability assessment and strengthen the scientific evidence of the assessment process. The detailed description is provided in the technical report KAERI/TR-7607/2019.

Proposed Technique

- Definition
  - Cue: information that can evidently remind the operator of the need for major actions of a human event of interest (a cue can be generated from procedures or instrumentations.)
  - Cue presentation time: the time that the cue is presented to a crew
  - Cue recognition time: the time when the crew perceives any need to respond to the presented cue
  - Cue activation period: the period in which the operator is actively aware of the need for major actions based on a specific cue
  - The end time of cue activation: the end point of the cue activation (usually, the sum of the cue presentation time and the cue activation period)
  - Critical cue: the first cue whose activation period substantially contains the recognition time of the last cue

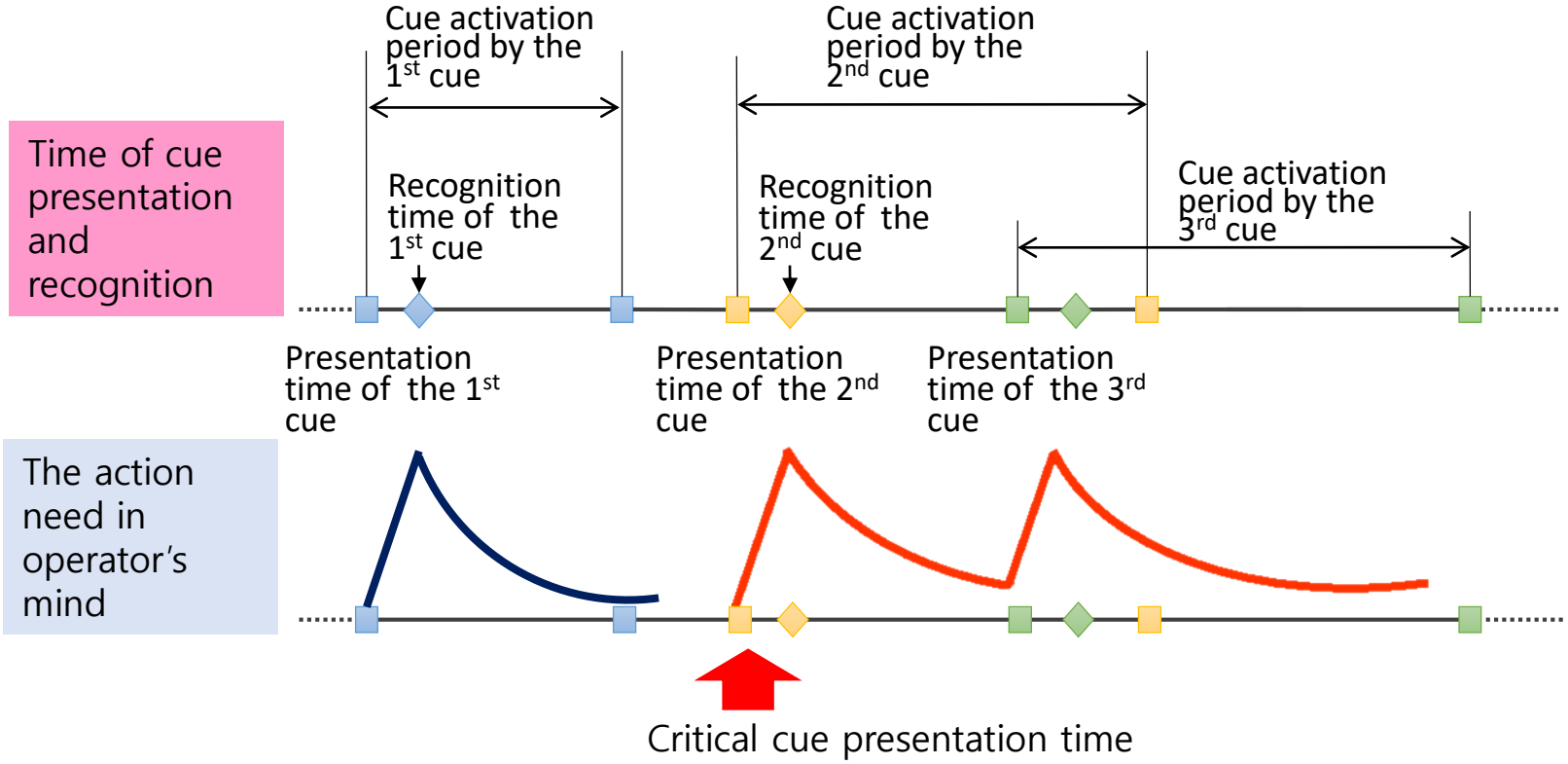


Proposed Technique

- Assumption
  1) The operators can initiate significant action relevant to an HFE when any cue presents.
  2) The operators follow procedures to cope with ongoing situations.
  3) All cues substantially remind operators of the need for major actions.
  4) There exists a cue activation period during which the operators can continuously think of the need for specific responsive actions.
  5) If the operator is proceeding with the procedural contents based on any cue, it is considered that the cue is actively recognized.

Proposed Technique

- Principle
  - The cue reminds the operator of the need for major actions.
  - After a certain amount of time, the need for action given by the cue could be forgotten.
  - If the additional cue is provided before the oblivion, the need is remained.



Proposed Technique

- Criterion proposed
  - After a certain amount of time, the need for action given by the cue could be forgotten.
    - The 95 percentile of the procedure following period between two steps addressing the cues
      - It is assumed that the operators do not remember the actions described in the relevant procedure after the 95 percentile period
    - Many studies revealed that the procedure following period could be described by lognormal distribution

      $Time_{95\%} = Time_{50\%} * \exp(1.645 * \sigma)$

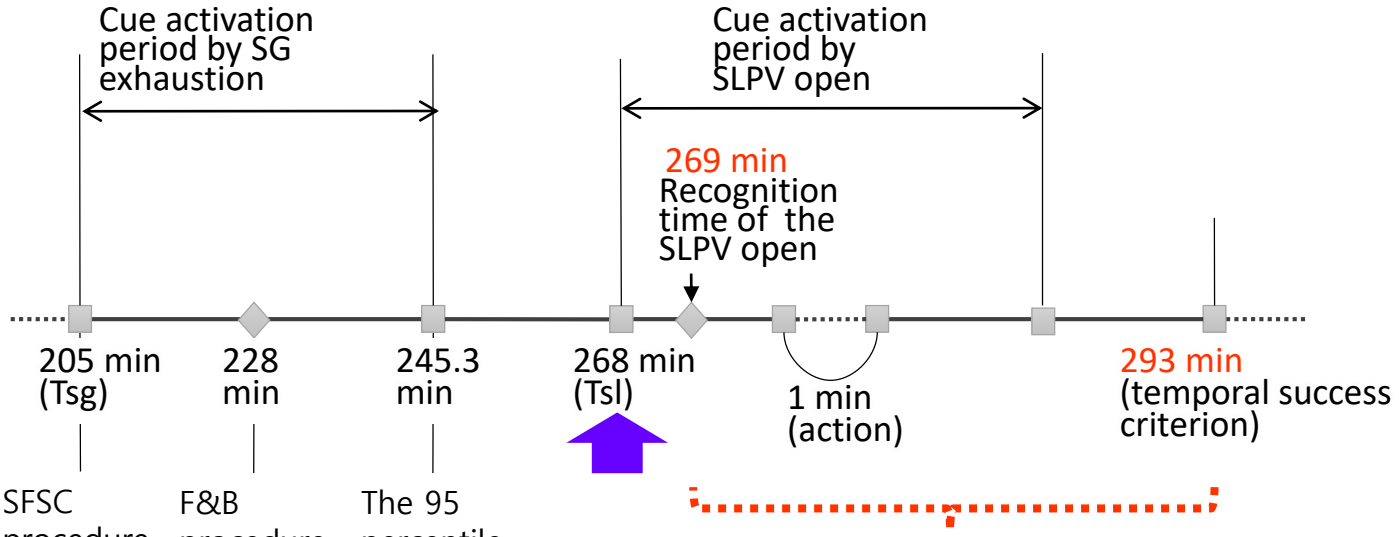
    - σ
      - EPRI estimates for PWR operators: 0.57
      - HuREX estimates for APR1400 operators: 0.3403 (ref. exp(1.645*0.3403) ≒ 1.75)

Proposed Technique

- Process
  1) Define the cues addressing the need for the major actions achieving the goals of a human event and regard them as the candidates of the critical cue
  2) Calculate the presentation time for each cue
  3) Identify the relevant procedure steps and sentences instructing the verification of each cue
  4) For each cue, estimate the 95 percentile of the time to follow the procedural steps between two neighboring cues and assert the 95 percentile of the time as the cue activation period
  5) From the initial cue of the selected event, check whether the end time of activation for each cue is higher than the recognition time of subsequent cue
  6) If the former is higher than the latter in (5), set the end time of current cue activation to the end time of subsequent cue activation, remove the subsequent cue from the candidates of the critical cue, and repeat (5) for the current cue and the cue after the second
  7) If the former is not higher than the latter in (5), remove the current cue from the candidates of the critical cue, and repeat (5) for the subsequent cue and the cue after the second
  8) After (5) to (7), determine the finally remained cue as the critical cue and calculate the TAD and the Diagnosis Error Probability for the given event.

Example (1)

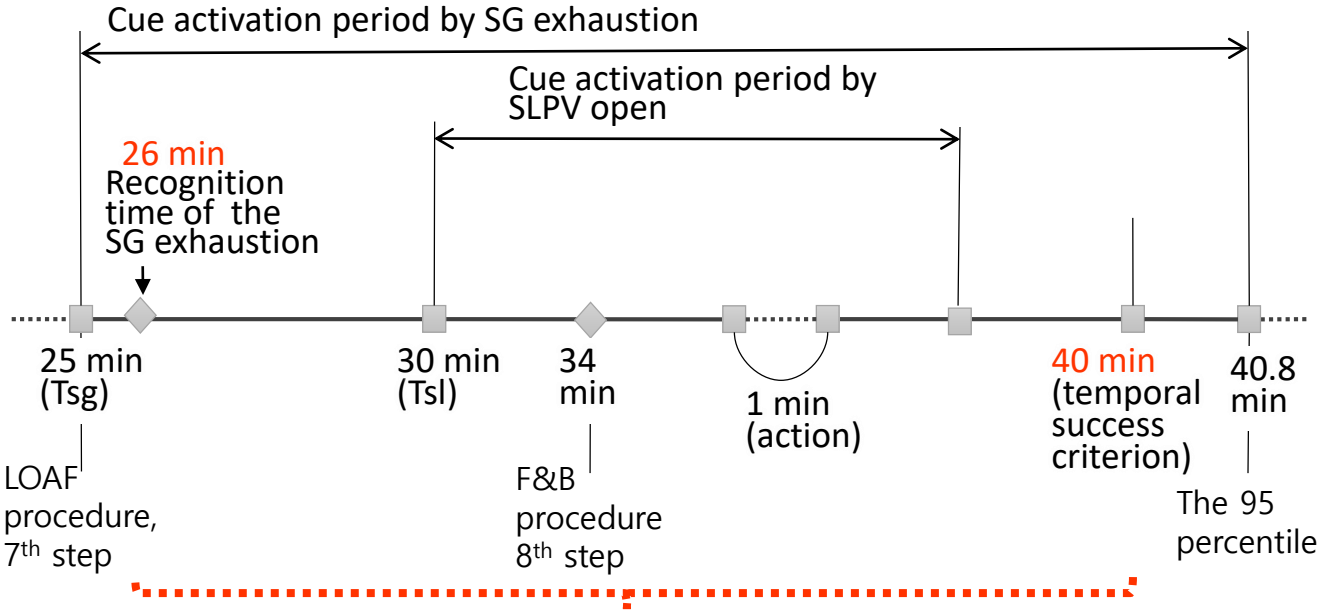
- Accident scenario 'A' in APR1400
  - Procedure step addressing SG exhaustion
    - SFSC procedure 5th step
  - Procedure step addressing SLPV open
    - FRP-F&B procedure 8th step
  - Median time between the two steps: 23 min
  - 95 percentile of the time : 40.25



The time available for diagnosis: 23 min

Example (2)

- Accident scenario 'D' in APR1400
  - Procedure step addressing SG exhaustion
    - LOAF procedure 7th step
  - Procedure step addressing SLPV open
    - FRP-F&B procedure 8th step
  - Median time between the two steps: 9 min
  - 95 percentile of the time : 15.75



The time available for diagnosis: 13 min

Summary of Case Study

Accident scenario	A	B	C	D
Instrumentation cue time of SG exhaustion (Tsg)	205	56	38	25
Instrumentation cue time of SLPV open (Tsl)	268	452	43	30
Procedure step addressing SG exhaustion	SFSC	SFSC	SFSC	ORP, 7th step
Procedure step addressing SLPV open	F&B operation procedure, 8th step			
Median procedure progression time between two steps addressing cues	23	23	23	9
Cue activation period	40.25	40.25	40.25	15.75
The end time of cue activation	245.25	96.25	78.25	40.75
	Λ	Λ	V	V
Cue recognition time of SLPV open	269	453	44	31
Critical cue time	Tsl	Tsl	Tsg	Tsg
Total time available	293	497	78	40
Time for recognition	1	1	1	1
Time for execution	1	1	1	1
Time available for diagnosis	23	43	38	13
Diagnosis error probability	2.37E-02	2.56E-03	3.87E-03	1.11E-01

Discussion and Conclusion

- A technique selecting the critical cue
  - For quantifying diagnosis error probability using the THERP's time-reliability curve
  - To reasonably select the presentation time of the critical cue
  - To minimize analyst-to-analyst variabilities and inter-analyst variabilities

- For accurate assessment
  - Assumption in the time reliability curve of THERP method
    - Depends on the absolute length of the time available that the operator can figure out how to cope with the situation
    - Does not consider how the crews progress procedures to recognize cue or manipulate systems/components
    - Kim and Park [2017] suspected that the time could not the only decisive factor of DEP in many cases. (c.f., K-HRA, HuRECA)
  - Qualitative analysis of cue and crew response
    - Timeline analysis with visualization
  - Credible time data source and representative estimates
    - Execution time from walkthrough or interview
    - Cue recognition time with consideration of procedure flow or operator stress

THANK YOU

yochankim@kaeri.re.kr